EVERY CHILD'S SCIENCE

Monteith

BLACKIE & SON LIMITED

17/Sc
8

~~1808~~

5313

M/Sc
8

2/5

SENIOR BASIC TRAINING COLLEGE
BANIPUR

1808 M/Sc
8
53/3

Every Child's Science

BLACKIE & SON LIMITED
66 Chandos Place, LONDON
17 Stanhope Street, GLASGOW

BLACKIE & SON (INDIA) LIMITED
103/5 Fort Street, BOMBAY

BLACKIE & SON (CANADA) LIMITED
TORONTO

~~1808~~ 5313
M/Sc
8

Every Child's Science

SENIOR BASIC TRAINING COLLEGE
BANIPUR.

BY

A. MONTEITH, B.Sc.

Library
Calcutta
13/3, B. C. Ro

BLACKIE & SON LIMITED
LONDON AND GLASGOW

S.C.E.R.T., U.P. LIBRARY
Date 23.8.05
Acc. No. 11838

Printed in Great Britain by Blackie & Son, Ltd., Glasgow

5313

SENIOR BASIC TRAINING COLLEGE
BANIPUR.

PREFACE

This book is intended for children of about eleven to thirteen years of age. The subject-matter is not presented in the usual sequence, for it has been found that the best preparation for later work is a good general knowledge of the laws of science, based on the children's experience in their everyday lives. Hence there are no exercises in measuring lengths, areas, and volumes, nor in accurate weighing and estimating densities. It is believed that these processes should be first learnt in connexion with the investigation of phenomena in which the child is naturally interested.

Neither has the subject-matter been divided under the usual headings of heat, chemistry, hydrostatics, &c. One branch has been allowed to merge into another, for when a child shows interest in water, he does not only want to know what it is made of, which chemistry would tell him, but also what it does, which physics would tell him.

A child should know the use of a barometer and thermometer, but he need not fully understand the principles underlying their construction. Pressure is a subject which a small child finds difficult to understand, hence only one aspect of it has been dealt with here.

With regard to drawings, the children should be encouraged to make rapid *sectional sketches*. Perspective drawing should be discouraged, as it wastes time and is usually very faulty.

The sketches of pieces of apparatus are intended to help the child to identify those mentioned in the text and required for the experiments.

A. MONTEITH.

May, 1932.

CONTENTS

CHAP.		Page
I.	THINGS THAT CHANGE THEIR FORM	1
II.	WHAT THINGS ARE MADE OF	9
III.	THINGS THAT GET LARGER AND SMALLER	15
IV.	THINGS THAT SHARE THEIR HEAT	24
V.	BOILING THE KETTLE	32
VI.	MAGIC HEAT	38
VII.	HOW WATER BREAKS THE RULES	43
VIII.	THE UNSEEN FORCE THAT PULLS US ALL	50
IX.	THE UNSEEN FORCE THAT PRESSES ON US ALL	56
X.	A MIXTURE ON WHICH OUR LIVES DEPEND	62
	APPARATUS	69

EVERY CHILD'S SCIENCE

CHAPTER I

Things that Change their Form

When something disappears and no one knows where it is, you may say: " Things don't walk off by themselves, someone must have taken them!" Well, there *are* some things that *do* disappear without anyone taking them! Camphor or naphthalene is one of them. If you leave a lump of camphor on your table it will get smaller and smaller until it disappears altogether. Methylated spirits will escape from an uncorked bottle. Water is always disappearing. Put a saucer full of water on your window ledge and it will be empty in a few days. Great big puddles of water disappear in a few hours even when they are on hard pavements into which the water cannot soak. Drop a lump of sugar into a tumbler of water and it will disappear. Soap disappears in your bath and soda in the washing-tub.

Where do the camphor, methylated spirits, and water go? They change their form and become invisible. They are in the air all the time, only you can't see them (though indeed you may be able to smell the camphor). The water has become water vapour, or " water-gas ". The naphthalene has become naphthalene vapour. When moths breathe this vapour they die. If naphthalene did not turn to vapour or gas, it would not kill moths.

If water did not turn to water vapour the air would be uncomfortably dry and there would be no clouds, no rain, no dew, no snow, and no frost.

When substances disappear into the air like this they are said to "evaporate". So you may say: "My camphor has all evaporated," "The big puddle on the playground has evaporated," "Don't leave the cork out of that bottle or the methylated spirits will evaporate." *Evaporate* means to become a *vapour* or gas. More water evaporates on dry, warm or windy days than on damp, cold or calm days. The air is dry and so it can take in more, just as a dry sponge can take in more water than a wet sponge. On dry days the air has less water vapour in it than on damp days. When a sponge is so full of water that it cannot take in any more we say it is *saturated*. When the air is so full of water vapour that it can't take in any more, it is said to be saturated.

On windy days the water that has evaporated from a puddle is blown away, and so room is left over the puddle for more water vapour to rise.

Warm air can hold more water vapour than cold air, so on a warm day more water disappears.

A large shallow puddle will evaporate more quickly than a small deep puddle that has the same amount of water in it. This is because it is only the water on the top or surface that can evaporate. Test this by putting the same amount of water into a saucer and into a cup. Leave both in the open air; see which gets empty first. Water and all liquids must have heat to make them evaporate. They often take this heat out of whatever is touching them. The water in a puddle gets colder as some of it evaporates, and the soil under the puddle gets colder too.

The water you wash in is a *liquid*. When you pour it into your basin from the jug it takes the shape of the basin. Liquids always do this. They change their shape according to the vessel into which they are put. If you pour water from a cup into a soup plate there will be just the same amount of water in the plate as in the cup, that is, the *size* will not change but the *shape* will be different. If you pour water on the table it will make a flat puddle or run in streams down on to the floor. Liquids flow. Sand and snow are solids even though they can be made to take the shape of a tumbler or soup plate. They do not flow. You can heap them up. They are solids in very small pieces.

Water vapour is a gas, so is steam. Steam is hot water vapour. A gas, no matter how little there is of it, tends to fill the space in which it is. If you let some camphor or ammonia vapour escape in your room it will spread all through the room and you will be able to smell it everywhere. A gas, then, changes its size and its shape so as to fill the space into which it is put.

Water, if it is made very cold, will freeze and become ice. Ice is solid, so is snow. A lump of ice will not take the shape of the jug, basin, or plate into which it is put. It has its own shape, and unless you break it up it will not change that shape. A solid, then, has a size and a shape that cannot be easily changed.

Every substance might be made into a solid, a liquid, and a gas, but under everyday conditions some are solids, others are liquids, and others gases. To make them change they must be heated or cooled. For instance, in everyday life under ordinary conditions:

(*a*) The air is a mixture of the gases oxygen and nitrogen; but air becomes liquid on being cooled, and further cooling will change it into a solid.

(*b*) Mercury, glycerine, turpentine are liquids. They would become solids if they were cooled sufficiently, and gases if they were heated.

(*c*) Tin, lead, glass, naphthalene are solids. They become liquids and then gases on being heated.

The great difficulty is to get enough heat or cold to change substances from one form to another.

EXPERIMENT 1. *What to do*. Light a bunsen burner and turn it very low. Put a piece of naphthalene in a test tube. Holding it in a test tube clamp, heat it very gently. Then let it cool.

What happens? The naphthalene melts or becomes a liquid. When it cools, it solidifies or freezes.

EXPERIMENT 2. (*a*) Put a crystal of iodine on a piece of glass and watch it.

What happens?

(*b*) Put a few crystals of iodine in a test tube and heat them. *What happens?* (See fig. 1.)

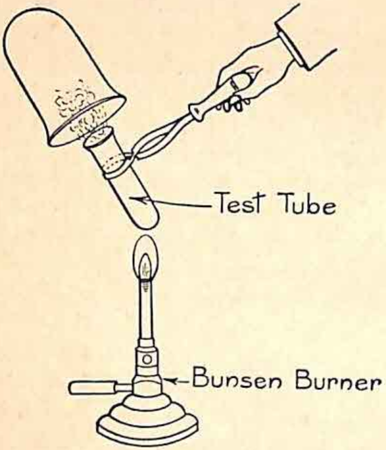


Fig. 1.—Iodine being heated in a Test Tube.
Tumbler held to catch the Fumes

(*c*) Hold a tumbler so as to catch the fumes.
What do you see inside the tumbler? Explain.

EXPERIMENT 3. *What to do.* Put some silver paper or tin foil in a crucible and heat it strongly. When it has melted take crucible tongs and pour the liquid on to a flat stone or piece of slate.

What happens?

EXPERIMENT 4. With a glass rod put a drop of methylated spirits on your hand.

What happens to it?

Why does your hand feel cold?

Experiment 5. Put a *little* water in a small flask and pour some ether over the outside of the flask. The ether evaporates, and in doing so takes heat out of the water inside the flask.

What happens to the water?

Why?

Experiment 6. What liquids are used in your home? Put the same amount of each in a saucer, then see which evaporates first. Be sure that they all have the same amount of heat, light, air, and surface exposed.

Now what becomes of the sugar you put in your tea, and of the soda in the washing-tub? They have completely disappeared. A person who has not studied science will say: "My sugar has melted." The sugar has not melted, it has dissolved in the water. To melt sugar we should have to heat it by itself until it became liquid sugar. When sugar is put into water it breaks up into tiny particles and spreads all through the water. You can taste it in all parts of the water. Such a mixture is called a *solution* of sugar in water.

Hot water will hold much more sugar than cold water. Take a tumbler of cold water and add sugar pinch by pinch. Stir all the time to make sure all the sugar dissolves. After a time you will find that no more sugar dissolves. The water is saturated. It cannot hold any more sugar. Heat the water and add more sugar. The hotter the water gets, the more sugar it will take in before it gets saturated. Let the hot solution cool; sugar will fall to the bottom. Cold water cannot hold as much sugar as hot water, so it has to drop some of it.

Water can dissolve a great many substances besides sugar. You know that sea water is salty. That is because when the rain falls on the ground it soaks into the earth and dissolves many of the substances there. Common salt is one of these substances. Every river and stream has a little common salt in it, and this salt is carried to the sea. The water in the sea evaporates, but the salt cannot evaporate so it is left behind. For thousands and thousands of years the rivers have been bringing a little salt to the sea and it has collected there, and that is why the sea is getting more and more salt.

EXPERIMENT 7. Which of these substances:
(*a*) dissolves in cold water?
(*b*) dissolves in hot water?
(*c*) will not dissolve at all?

Sulphur, copper sulphate, chalk, carbon, nitre.

EXPERIMENT 8. Put 3 pinches of salt into a small evaporating basin, add water. Heat it on a tripod with wire gauze and bunsen burner. When the water is boiling remove the burner (see fig. 2).

What has happened to the salt?

Go on heating the water until it has all disappeared.
What is left?

LEARN THIS:

Solids do not readily change their size or their shape.

Liquids do not readily change their size, but they change their shape.

Gases readily change both their size and their shape.

Study fig. 3 and learn to interpret it thus:

Reading up the dotted line or " hot " side:
Solids when heated melt and become liquids.
Liquids when heated evaporate and become gases.
Solids must take in heat to turn to liquids.
Liquids must take in heat to turn to gases.

Reading down the " cool " side:
Gases when cooled condense to liquids.
Liquids when cooled solidify or freeze into solids.
Gases give out heat when they become liquids.
Liquids give out heat when they become solids.

Evaporation is the turning of a liquid into a gas.

Evaporation is helped by wind, warm air, and large surface exposed.

Evaporation goes on always, even snow and ice turn to water vapour.

Water is a good *solvent*.
Many substances *dissolve* in water.
Sea water is a *solution* of several salts in water.
When the water evaporates the salts are left behind.

QUESTIONS

1. Why do people in a hot desert wet the outside of their water bags to keep the water cool?

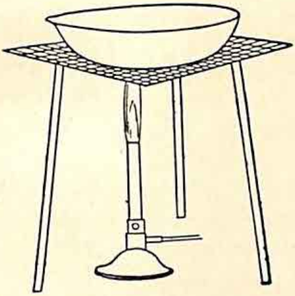


Fig. 2.—Evaporating solution of salt

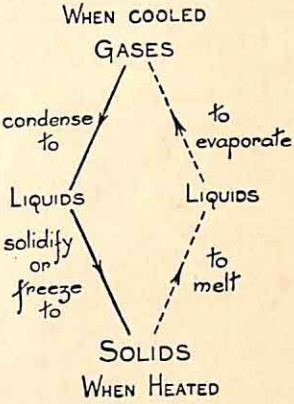


Fig. 3

2. When a tumbler of cold water is brought into a hot room, why are drops of water often found on the outside of it?

3. Why are wet clothes hung out to dry?

4. Why do you feel cold when your clothes are wet?

5. Why does petrol make your hands colder than water does?

6. Why does melting ice keep butter cool on a warm day?

7. Fill in the missing words:

(*a*) A —— has a definite —— and a definite ——.
A —— has a definite —— but no definite ——.
A —— has no definite —— and no definite ——.

(*b*) Gases —— when cooled.
Liquids —— when cooled.
Liquids —— when heated.
Solids —— when heated.

(*c*) —— air holds more water vapour than —— air.
When warm air is cooled the water vapour in it ——.

8. Write " yes " if a statement is true and " no " if a statement is false.

(*a*) There is no other substance except water that has three forms: solid, liquid, and gas.

(*b*) Powdered chalk can be poured into a glass, so it must be a liquid.

(*c*) Water vapour that goes into the air never comes out again.

(*d*) Most metals are solids under ordinary conditions.

(*e*) A puddle of water is made cooler by water evaporating from it.

(*f*) Moths eat naphthalene and are poisoned.

(*g*) To dry clothes the best plan is to warm them in front of a fire.

(*h*) Wood will not melt in water.

9. What do you mean when you say: " My tea is saturated with sugar "?

10. Why is the sea salt?

11. How could you get the salt out of sea water?

CHAPTER II

What Things are Made Of

All the things that you see and feel are made of substances called elements. There are about eighty elements which are known by men who study science. Here is a list of some of them. (Never mind the Latin words or the letters for the present.)

Aluminium, Al.
Calcium, Ca.
Copper (cuprum), Cu.
Gold (aurum), Au.
Iron (ferrum), Fe.
Lead (plumbum), Pb.
Magnesium, Mg.
Manganese, Mn.
Mercury (hydrargyrum), Hg.
Nickel, Ni.
Platinum, Pt.
Potassium (kalcium), K.
Silver (argentum), Ag.

Sodium (natrium), Na.
Tin (stannum), Sn.
Zinc, Zn.
Sulphur, S.
Carbon, C.
Silicon, Si.
Iodine, I.
Phosphorus, P.

Oxygen, O.
Nitrogen, N.
Hydrogen, H.
Chlorine, Cl.

Just as in the alphabet there are twenty-six letters which may be joined together in different ways to make words, so these eighty elements or simple substances may be joined together to make compounds. Now the letter O makes the word "owl" when it is joined to w and l; and it makes the word "dog" when it is joined to d and g; but owl and dog are quite different words, and do not sound like O or like each other. The element iron joined to oxygen makes iron-rust, which is not a bit like iron or oxygen. So letters may be likened to elements, and words to compounds. You cannot put just any letters together to make a word. There are no words spelt "xyz" or "abc", are there? Neither can you put any elements together to make a compound. Some elements won't join together at all: and others are always trying to join.

If you are a good reader you will know what letters are in a word. You can see them; but in a compound you cannot see the elements. For instance, you would never know by looking at common salt that it was made up of sodium, a metal something like silver, and a yellow poisonous gas called chlorine! Neither could you see the black carbon or charcoal that is in sugar and marble. You must "unmake" a compound to find out of what elements it is made.

Now to unmake a compound is very difficult. To make compounds from elements is not so easy as to make words out of letters. It is not always enough to put the elements together, you have to do something to them to make them join. Sometimes you must heat them.

EXPERIMENT 9. To make a compound from two elements, iron and sulphur.

What to do. Take some iron filings and mix them with powdered sulphur. No matter how carefully you mix them, you will be able to see the yellow sulphur. It is not united with the iron, but is only mixed with it. Now heat the mixture in a hard glass test-tube. It will probably go on fire. Stop heating it. It will go on sparking and glowing. When it is cool you will find that the sulphur and the iron cannot be distinguished. They have joined to make quite a new substance. This substance is called iron-sulphide.

EXPERIMENT 10. To unmake a compound.

What to do. Take some red powder called oxide of mercury and put it into a test-tube. Heat it. Hold a glowing splinter of wood in it. What happens? It will turn dark red, but after a time you will see a gas coming off and bright silvery globules shining on the side of the tube.

Just as there are words with two, three, or more letters, so there are compounds with two, three, or more elements. It is easy to count the letters of a word, but impossible to count the elements in a compound.

Many substances have two names. One is their common or everyday name, and the other is their chemical name. For instance we say " common salt ", " washing soda ", " chalk ", and " red lead ", whilst scientists say "sodium chloride ", "sodium carbonate", "calcium carbonate ", and " lead oxide ". A compound is only given a chemical name when people have found out what it is made of. Chemical names tell secrets. They tell you how many elements there are in a compound. If the name ends in " ide " there are two, and if it ends in " ate " there are three, and one of them is oxygen. Look at the list of elements and find out which are in the three compounds named above. Some common compounds are: wood, glass, silk, salt, water, marble, ink, paper, gum, meat, sand, vinegar, paint, potatoes, tea, milk, lime, stones, wool, sugar, camphor, chocolate, and acids.

You should begin to make a collection of elements. You might keep them in match-boxes or else in a partitioned box, like an egg-box. Which elements are you not able to keep in a box? Which are dangerous to keep? When you have got all the elements you can, then begin to collect compounds. Write on each the names of the elements contained in it. You might use the shorthand way given in the table. Instead of writing " sulphur " write S, and instead of " calcium " write Ca, and so on.

Every substance has properties, that is, it has characteristics or qualities by which we may recognize it. Iron is heavy, it turns red when heated, it is hard and rigid; it does not burn, it is solid under everyday conditions; all these qualities are called properties. So when you describe a substance you are really telling its properties—what it looks like and what it does. Think of its form, colour, taste, smell, weight; whether it is hard or soft; soluble in water or not; whether it burns or lets things burn in it; what happens when it is heated and cool; with what substances it joins.

Among the elements on page 9 there are metals and non-metals. They are divided into these two groups because of their properties. Metals have a shine which we call metallic lustre. They are nearly all heavy and they let heat and electricity pass through them. Non-metals have just the opposite properties. Pick out all the metals on page 9. Which metal is not heavy? How many non-metals are gases? How many are liquids?

When a change in a substance does not last and does not alter its weight, we say it is a *physical* change. For instance when you heat a poker it gets red hot. When you stretch elastic it gets long. When water freezes it turns to ice.

When, however, a change is lasting and there is a change in weight and in other properties, the change is called *chemical*. After a chemical change you do not find the same substance as you had before. New substances have been made. Examples of chemical changes: when a piece of paper burns, when milk turns sour, when iron rusts, when gunpowder explodes. When a chemical change takes place heat, light, and sound may be given out.

EXPERIMENT 11. *What to do*. Heat a piece of sulphur in an evaporating basin. When it has all melted take away the burner

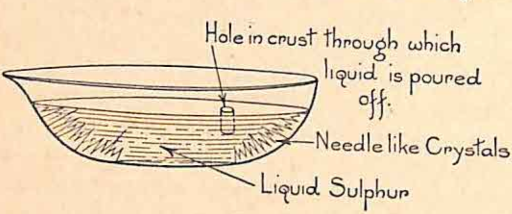


Fig. 4

and watch carefully. Make a hole in the crust of the sulphur and pour away the liquid sulphur from underneath. Turn over the crust. What has happened? Is it a physical or chemical change?

EXPERIMENT 12. *What to do.* Weigh six inches of magnesium wire: weigh an evaporating basin. Hold the wire in the crucible tongs and set fire to it. Catch all the ash in the evaporating basin. Weigh the ash and the dish. Find the weight of the ash alone.

What has happened? If you have done this experiment carefully you will find that the ash weighs more than the magnesium wire. When it burned the magnesium joined with the oxygen in the air, and made magnesium-oxide. In what ways is the "ash" different from magnesium?

EXPERIMENT 13. Take a needle and a magnet. Stroke the needle from eye to point. Do this again and again. Never stroke from point to eye.

What happens? Is this a physical or a chemical change?

EXPERIMENT 14. Put a pinch of salt in a tablespoonful of water, pour it into a saucer, and leave it on the window ledge in the sun.

What happens? Is this a physical or a chemical change?

EXPERIMENT 15. Put a drop of hydrochloric acid on a piece of chalk or marble.

What happens? Is this a physical or chemical change?

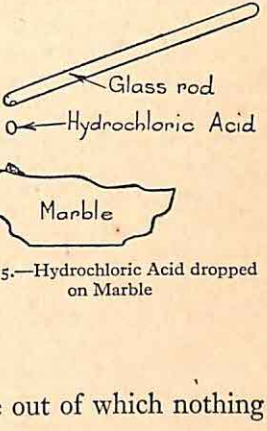


Fig. 5.—Hydrochloric Acid dropped on Marble

LEARN THIS:

An element is a simple substance out of which nothing can be got but itself.

A compound is made up of two or more elements joined to form an entirely new substance unlike any of the elements in it.

Iron is an element. In iron there is nothing but iron.

Iron-rust is a compound. In rust two elements, iron and oxygen, are joined.

A chemical change is lasting, and a new substance is made.

A physical change is not lasting, and no new substance is made.

Metals have a metallic lustre. They are heavy and allow heat and electricity to pass through them.

QUESTIONS

1. What is an element? What is a compound?

2. Name six elements that you know are heavy.

3. Which of the elements in the list on page 9 are used to make things that are in your kitchen?

4. What are the following used for: gold, silver, zinc, carbon, iodine?

5. What are some of the properties of sulphur?

6. Name a physical change you could make with each of the following: a knitting needle, charcoal, butter, ice.

7. Name a chemical change that you could make with each of the following: bread, sugar, cheese, and a match.

8. Write out Experiments 11 and 12 under the headings: "What to take", "What to do", "What happens?" and "Why?"

9. In Experiments 1, 2, 3, and 4, are the changes physical or chemical?

CHAPTER III

Things that get Larger and Smaller

When you were little you perhaps had a Jack-in-the-box among your toys. You remember how on undoing the little hook, the lid would fly open and Jack would pop out! Jack's body has a spring made of steel inside it. All the time the box is shut Jack's head is pressed hard against the lid—because the spring inside him is trying or tending to get as long as it was before the box was shut.

A substance that tends to spring back to its old shape or size after it has been squeezed small or pulled out long is said to be elastic. If you look round the house you will find many things with steel springs—beds, chairs, doors, clocks, blinds, paper clips, &c. There will also be things made of rubber, and others of rubber filled with air. Air is made of gases and so has no shape of its own—but it has size. When a ball is bounced on the floor a dent is made in the rubber, it is knocked in by the floor, and the air inside is compressed or made to take up less room. But rubber is very elastic and goes back at once to its former shape, and the compressed air goes back to its former size, so the ball gets a " push off " on the floor and bounces. Bicycle and motor-car tyres of rubber with air inside act like springs, and make the vehicle bounce over small obstacles. If you have ever had a ride in a wheelbarrow you will remember how you were bumped about. This is because it had no tyres or springs.

We can then make things change their shape and size by pulling them out or by pushing them in—but there is another way. If you look at telephone wires on a cold day you will see that they are straight, tight, or taut. On a hot day they hang down or sag. This is because the heat has made all the wires expand or grow bigger, and they are now too long so that they hang down loosely. When the cold weather comes again they will contract or get smaller again and be quite straight and taut. Heat makes things expand, and cold makes them contract.

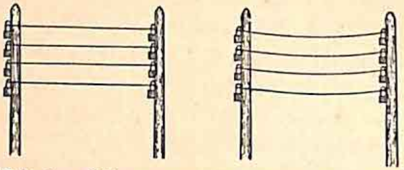


Fig. 6.—Telephone Wires are taut in Winter and "sag" in Summer

If you look carefully at a cold oven you will see that the bars are loose. If they were fixed they would all bend when the gas was lighted, because the heat would make them expand. Hot-water pipes have big joins, one pipe fits inside the other. When the water is hot both pipes can expand, one along the outside and the other along the inside. A railway line has spaces here and there because when the train goes over it, it gets hot and expands. When it is hot the spaces close up and when it cools the spaces open. The spokes of a wheel have to fit very tightly into the axle. The wheelwright puts an iron band round the wheel. He puts this band on while it is hot. As it cools it contracts and pushes all the spokes in tightly.

In the Sahara desert the days are intensely hot and the nights are very cold. During the day the rocks get heated and they expand. At night they get very cold and contract. This repeated expanding and contracting at length makes the rocks split. The pieces in their turn are heated and cooled until they too break. In this way large rocks are broken into smaller and smaller bits until at length the wind blows them away and they become sand.

If you fill a kettle to the very brim and then heat it, the kettle itself will expand and the water will sink a little. After a time the heat reaches the water and it expands much more than the kettle did and so it overflows. Water, as you know, is a liquid, and all liquids expand more than solids.

The fact that liquids expand when heated is used in the construction of a thermometer. " Thermo " means " hotness " and meter means measure. The thermometer is an instrument for measuring " hotness ". Suppose you put your hand on to the top of a hot oven, the oven would heat your hand. The " hotness " or " temperature " of the oven was greater than that of your hand. If you put your hand into cold water, you would feel cooler, because heat flows from your hand into the water. The hotness or temperature of your hand was higher or greater than that of the water, and so you lost heat and the water gained heat. By comparing the temperature or hotness of two bodies we can find out which would part with heat to the other if they were put together, or which is at the " higher level of heat ". Temperature means hotness, or level of heat, or degree of heat.

A thermometer is a closed tube with a bulb at one end. In the bulb and part of the tube there is mercury, and this mercury expands when the bulb is warmed and it contracts when the bulb is cooled. There is no air in the tube. The space above the mercury is *really empty*. Such a space is called a vacuum. If there were air the mercury would not have room to move up—because the air would expand too. On a thermometer there are a lot of marks called graduations. These show degrees of heat. There is one near the lower end marked 0. When the thermometer tube was first filled with mercury there were no marks on it. It was put into ice. This made the mercury contract. The level of the mercury when it was in ice was marked o° and called "naught degrees". Then the thermometer was put into steam and the level was marked 100°. The space between the o° and the 100° was carefully measured and ninety-nine little marks were made dividing it into one hundred equal little parts.

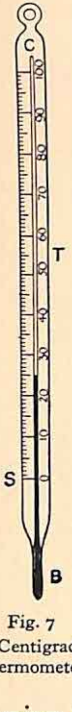


Fig. 7
A Centigrade Thermometer

Now, if the thermometer is put into some liquid and the mercury falls to o°, then we know that the temperature of that liquid is the same as the temperature of ice. There is heat in ice. By adding salt to ice you can take some of this heat out of the ice, and the mercury will fall below o°. So o° does not mean "no hotness", it means the same temperature or "hotness" as that of ice. One hundred degrees means the same temperature or "hotness" as that of boiling water.

Now perhaps from all this you can guess why a thermometer graduated in this way is called a Centigrade Thermometer? If you look in your arithmetic book you will see, under the Metric System, a good many words beginning with "cent". We also speak of a "century", which means a hundred years, and on French stamps and coins you will see "centimes".

Mercury is used for thermometers because:

Firstly, it will stand great heat without turning into a gas. That is to say the boiling-point of mercury is very high (357° C.).

Secondly, mercury has to be made *extremely* cold (—39° C.) before it will become a solid. If mercury boiled at a low temperature the tube would break, and if it became a solid easily it would be useless. So we say mercury has a *large range* of temperature. It stays liquid from 39° below the freezing-point of water right up through 0° and 100° to 357° C. So it may be used with safety for finding the temperature of very hot and very cold things.

Thirdly, mercury can be seen easily. It is opaque, and not transparent like water or glycerine.

Fourthly, mercury expands very evenly.

Fifthly, mercury gets hot and cold quickly so that you have not long to wait for it to go up or down.

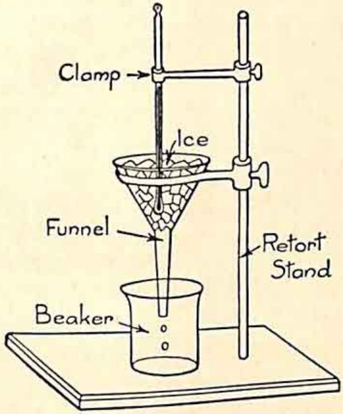


Fig. 8 *a.*—Thermometer in Ice

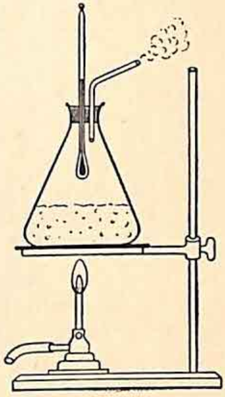


Fig. 8 *b.*—Thermometer in Steam

LEARN THIS:

Elasticity is the tendency of a substance to go back to its former shape or size after it has been forced into a different shape or size. Solids, liquids, and gases expand when heated and contract when cooled. Some solids and liquids expand and contract more than others. For instance: Zinc expands more than iron and iron expands more than glass. Alcohol or methylated spirits expands more than water, and water expands more than mercury.

All gases expand and contract the same amount if heated or cooled to the same degree.

Gases expand and contract much more than liquids, and liquids more than solids.

SENIOR BASIC TRAINING COLLEGE BANIPUR

A thermometer is an instrument for measuring temperature or hotness. With it we compare the hotness of a substance with that of water.

0° C. is called freezing-point, and 100° C. is called boiling-point. 0° does not mean "no hotness" but it means the "same hotness" as that of ice. "Cold" is absence of heat, as darkness is absence of light. Every substance has *some* heat in it.

Experiment 16. To show that iron expands when heated and contracts when cooled.

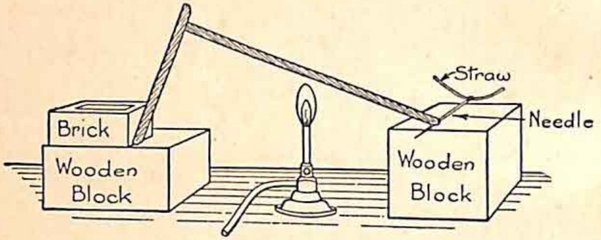


Fig. 9.—To show that an Iron Bar expands when heated

What to take. Retort stand, wooden blocks, needle, straw, sealing-wax, bunsen burner.

What to do. Fix retort stand so that the long bar slants, as in fig. 9. Fix a piece of straw with sealing-wax on to the eye of a needle. Rest the free end of the bar on the needle so that when the bar expands it will roll the needle round (like a wheel).

What happens?

Why?

Experiment 17. To show that heat makes iron expand and that cold makes it contract (see fig. 10).

What to take. The "ring and ball".

What to do. Pass the ball through the ring. Heat the ball. Try to pass it through the ring. Let it cool.

What happens?

Heat the ball again. Let it rest on the ring.

What happens?

1808
n/sc 8

SENIOR BASIC TRAINING COLLEGE BANIPUR

EXPERIMENT 18. To show that liquids expand when heated.

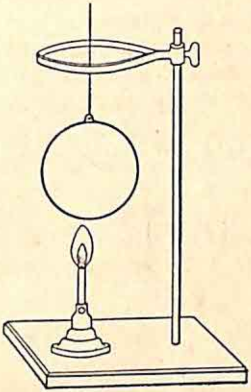


Fig. 10

What to take. 3 flasks of same size with corks and long tubes, turpentine, glycerine, water (see fig. 11).

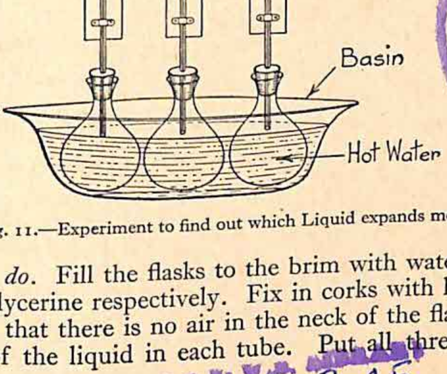


Fig. 11.—Experiment to find out which Liquid expands most

Library
25/3, B. C. Road

What to do. Fill the flasks to the brim with water, turpentine, and glycerine respectively. Fix in corks with long tubes. Make sure that there is no air in the neck of the flask. Mark the level of the liquid in each tube. Put all three flasks at

23.8.05
11838

the same time into a basin of warm water so that all are equally heated.

What happens?

Which liquid expands most? Why must the flasks be the same size? Why must there be no air in them? Why do the liquids fall slightly when the flask is heated?

Experiment 19. To show that air expands when heated.

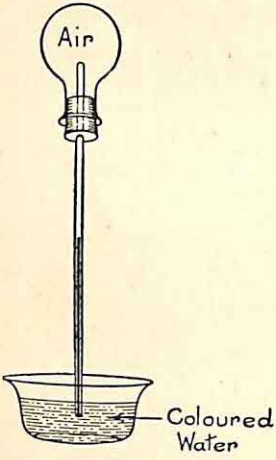


Fig. 12

What to take. A small flask or bottle fitted with a long tube and a cork; dish of coloured water.

(We often call a flask like this " empty ", but it is not really empty, it is full of air.)

What to do. Turn the flask upside down so that the end of the tube is under water in a dish. Heat the flask with a match.

What happens?

Why?

Let the flask cool.

What happens?

Why?

QUESTIONS

1. Why are the iron bars in a grate loose?

2. Why is it a mistake to tighten the screws that hold glass lamp globes?

3. In Experiment 19, when the water rose up the tube, was it pushed or pulled up?

4. What exactly is in a thermometer?

5. Cold is absence of heat, just as darkness is absence of light. What do we really mean when we speak about "making" a thing very cold?

6. When the reading on the thermometer is at 0°, does it mean that there is no heat in the substance? What does it mean?

7. Why is mercury chosen for thermometers? What would happen if water were used?

8. Have you ever had your temperature taken with a centigrade thermometer? What is it when you are quite well? Is that hotter or colder than the air in your room?

9. Why is it dangerous to pour very hot water into a thick glass tumbler?

10. How would you loosen the glass stopper of a bottle?

11. Find out through how many degrees the temperature of the air rises or falls between 9 and 12 o'clock and between 12 and 4 o'clock.

CHAPTER IV

Things that Share their Heat

Perhaps you have sometimes been allowed to pour out tea. You may have found the silver teapot handle too hot to hold and then you probably used a woollen holder. But if your teapot was a china or earthenware one, the handle would not be too hot to touch and so you would not need a holder.

Silver, copper, and most other metals let heat pass through them. They are called *good conductors of heat*. In the case of the silver teapot the heat travelled from the hot water to the particles of silver inside the pot and touching the water. These particles immediately passed some of their heat to the particles touching them, and these, in their turn, passed some heat on, so that at last the handle got too hot to touch. In the handles of most silver teapots you will see two pieces of ivory or ebonite. Ivory and ebonite are bad conductors of heat. This means that heat does not pass through them easily. Each particle keeps its heat and does not pass it on to particles touching it. Pieces of these non-conductors are put into the handles of teapots to prevent the heat passing into them and making the handles too hot to hold.

Wool is a bad conductor. You use a woollen holder so that the heat can't get through from the handle to your hand. Earthenware is also a poor conductor and so teapots made of it do not get too hot to hold.

The following lists will help you:

Good conductors: silver, copper, iron, steel, brass, aluminium, nickel, zinc, lead, and most other metals.

Feeble conductors: brick, stone, marble, slate, glass.

Bad conductors: wood, bone, felt, wool, paper, feathers, cork, fur, leather, water, *air*.

A vacuum or empty space does not let any heat pass through it by conduction.

If you feel the different objects in your room, some will seem cold and others warm, yet all are at the same temperature really. Those that seem cold are good conductors. Your temperature is higher than theirs, so that when you touch them some heat goes out of you into them, and is passed along from particle to particle.

Bad conductors feel warm, because they do not take heat out of your hand. The particles actually touching your hand may get a little hotter, but they do not pass this heat on.

We use bad conductors of heat:

(1) To keep things hot, and
(2) To keep things cool.

We wear clothes which are made of wool and silk to keep us warm. Wool and silk are bad conductors. They keep *in* the heat of our bodies. They prevent it passing out.

We wrap up ice in flannel to keep it cool. The flannel is a bad conductor and will not let the heat of the room pass through to the ice.

Tea can be kept hot in a thermos flask. Such a flask consists of a small bottle inside a bigger bottle. The bottles are sealed together at the top and the air is pumped out of the space between them. The empty space or vacuum round the inner bottle is a perfect non-conductor. It is better for keeping in the heat than flannel or silk would be.

Thermos flasks are also used to keep water cool. The vacuum then keeps the heat *out*.

Eiderdowns are very warm. They do not give us heat but they prevent the heat of our bodies escaping. They are made of feathers, which are bad conductors. Besides being bad conductors themselves, there is a great deal of air between the parts of a feather and air is also a bad conductor. So it is the feathers and the air in them that keep the heat in.

Now though we talk of heat " travelling " and " passing " or " being conducted " you must not think of heat as a *thing*. Suppose you put 12 books standing up side by side on the table and that then you gave the end one a tiny push. Down would fall all the books. Number 1 would push number 2 and number 2 would push number 3, and so on till number 12 fell over too. The books did not change their places, it was your *push* that " travelled " along and made all the books fall. The tumble of the books was really caused by your little push.

The heat that you feel is really caused by the quivering or trembling of tiny particles of matter. Molecules is another word for particles so small that you can't see them. When the hot water is poured into a silver teapot the molecules of silver it touches start quivering or vibrating faster. Then the neighbouring molecules also begin vibrating faster, and so it goes on until the vibrations reach the handle of the teapot and you feel that it is getting hot. This feeling of heat is the result or effect of the quick vibrations. Just in the same way the tumble of the books was the *effect* of your push. Your push was the *cause* and the tumble was the *effect*. The rustle of the leaves of a tree is the effect or result of the breeze making them vibrate and knock gently together. The vibrating and knocking together is the *cause* and the rustle is the *effect*.

Heat then is the vibrating of molecules.

It is an interesting thing to think that all the molecules of the wood of the table, of your book, of your hand, are vibrating though you cannot see them. The molecules in ice are vibrating because, even though ice seems to us so cold, there is some heat in it.

Experiment 20. To find out which is the best conductor: copper, iron, or lead.

What to take. Rods of the metals, cork with 3 holes (or a piece of cardboard), beaker, boiling water, wax.

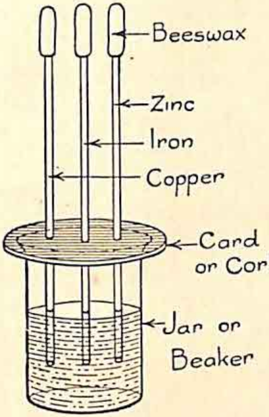


Fig. 13.—Experiment to show which Metal conducts Heat best

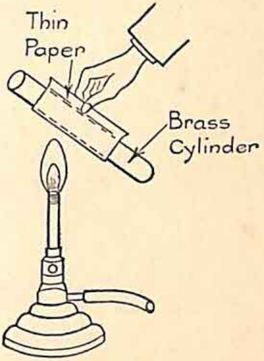


Fig. 14

What to do. Stand the rods up in a beaker or can (see fig. 13) by passing them through a large cork. Dip the upper ends of the rods in melted wax. Pour boiling water into the beaker. Put the cork in so that it does not fit tightly, and the rods all dip an equal distance into the water.

What happens? (Watch the wax.) If necessary, heat the water a little.

Why?

Experiment 21. To show that brass is a better conductor of heat than wood.

(*a*) *What to do.* Take a brass cylinder and wrap a piece of thin white paper round it (see fig. 14). Hold it in the flame of a bunsen burner.

What happens?

(*b*) *What to do.* Wrap a piece of thin white paper round a wooden cylinder and hold it in the flame a few seconds.

What happens?

Why?

Every substance has a "burning", "firing", or *ignition* point. This means that every substance when it reaches a certain temperature called "ignition" point, goes on fire.

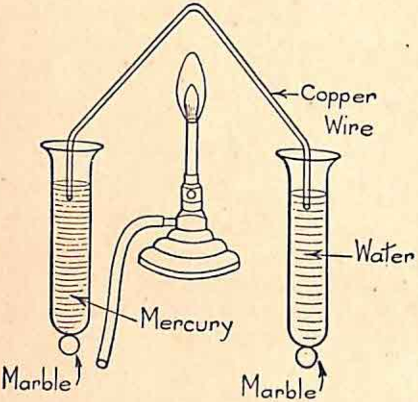


Fig. 15—Which is the best Conductor of Heat: Mercury or Water?

If you can keep a substance from reaching its ignition point you stop it scorching or going on fire.

How did the brass stop the paper from going on fire?

Try the same experiments using thick paper. Explain the result.

Experiment 22. To show that mercury is a good conductor and that water is a bad conductor.

What to take. Two test-tubes of equal size, marbles, bees-wax, water, mercury, retort stand, copper wire.

What to do. Fix a marble on to the end of each, using bees-wax. Pour mercury into one tube and water into the other. Set them upright in a retort stand (see fig. 15). Bend a strong piece of copper wire and heat it until it is red-hot. Hold the wire so that one end dips in the mercury and the other in the water.

What happens?

Why?

EXPERIMENT 23. To show that copper is a good conductor of heat.

What to do. Coil some wire round a thick pencil. Lower the coil so that it surrounds the flame of a candle or spirit lamp (see fig. 16).

What happens?

Why?

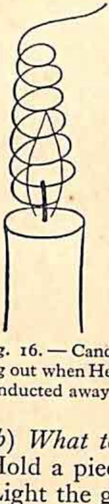


Fig. 16. — Candle going out when Heat is conducted away.

Hold the wire in a bunsen burner until it is red-hot.

Repeat the experiment. Explain results.

EXPERIMENT 24. To show the action of wire gauze.

(*a*) *What to do.* Light a bunsen burner.

Hold a square of wire gauze above the flame and then lower it gently into the flame.

What happens?

Why?

What happens if the gauze is left until it is red-hot?

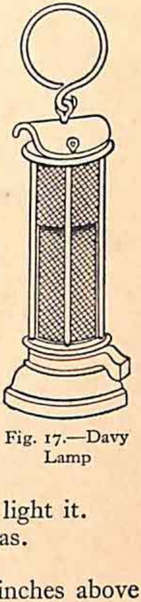


Fig. 17.—Davy Lamp

(*b*) *What to do.* Turn on the gas but do not light it.

Hold a piece of wire gauze ¼ inch above the gas.

Light the gas above the gauze.

Move the gauze up slowly, till it is about 2 inches above the flame.

What happens?

Why?

A wire gauze by cooling a flame prevents it from passing through and setting fire to gases on the other side.

A Davy lamp (see fig. 17) has wire gauze all round it. When a miner comes to a place where there is a dangerous inflammable gas, some of the gas passes through the gauze and burns inside the lamp with a blue flame. This warns the miner that he must move away. If he does not take the warning the flame inside may heat the wire gauze so much that it reaches the ignition temperature of the dangerous gas. Then there will be an explosion, for the gas will go on fire. It would look as if the air were burning.

LEARN THIS:

A molecule is a tiny particle of matter that is always vibrating.

The hotter a substance becomes the quicker the molecules move.

Heat is the vibrating of molecules.

Heat travels from particle to particle in good conductors.

Most metals are good conductors. Silver and copper are the best.

A good conductor is a substance that passes on heat from particle to particle until the whole is heated.

A bad conductor is a substance that, though it may get hot in one place, does not pass on the heat.

Wool, wood, and air are bad conductors. One particle of air does not pass heat to the particle next to it.

A vacuum is a perfect non-conductor.

Non-conductors are used: (1) to keep things warm by not letting the heat out; (2) to keep things cold by not letting heat in.

Conduction is the passing of heat from particle to particle.

The ignition point of a substance is the temperature at which it goes on fire.

Wire gauze when put into a flame conducts away heat. It prevents gases which are above it from going on fire.

QUESTIONS

1. Why is it incorrect to say that a piece of flannel wrapped round ice " will keep the cold in "?

2. Why is fur so warm?

3. Why do you use a cotton cloth to hold a hot dish?

4. Why does a robin puff out his feathers when he is cold?

5. If you want to make ice cream, why should you take: (1) a wooden pail to hold the ice and salt, and (2) a metal box to go inside the pail and hold the cream?

6. What would happen if you put 5 spoons made of different substances into a cup of hot water? Which would heat most and which least?

7. Is it true that to cool your tea it is a good plan to put a silver teaspoon into it?

8. Explain how it is that a Davy lamp prevents explosions.

9. When you take hold of a spade, why is it that the metal part feels so much colder than the wooden part?

10. Why are you advised not to sit on stone?

11. Why are mats for hot dishes often made of cork?

12. Which of the following has the highest and which the lowest ignition point: phosphorus, iron, wood, celluloid, paper?

CHAPTER V

Boiling the Kettle

You have often seen a kettle boiling, and you know that the water is "on the boil" when the kettle "sings" and when the steam comes out in a straight and steady stream. (See fig. 18.)

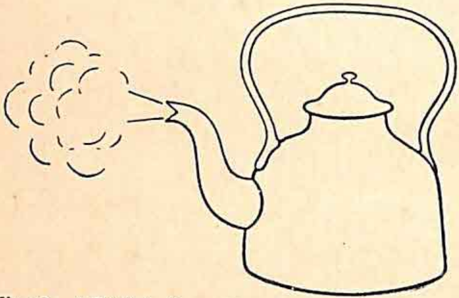


Fig. 18.—A Kettle boiling. Notice that the Steam near the Spout cannot be seen.

EXPERIMENT 25. To understand what happens when cold water is heated until it boils, you must set up the apparatus shown in fig. 19 and sprinkle a few magenta crystals or grains of sawdust in the water. Watch the water and notice these six things:

Firstly. Tiny bubbles rise through the water. These are made of air. Water has some air mixed with it. Fishes and plants need this air to breathe. When the water is heated the air in the water gets hot too and it expands (or gets bigger), grows lighter, rises in bubbles, and escapes into the outside air.

Secondly. The movement of the sawdust shows that there is a current in the water which goes up the middle and then spreads out and comes down the sides. You can make a current in a basin of water by stirring it round, but your current will go round and round and not upwards and downwards. The current in water that is heated from below goes upwards and downwards. The water nearest the flame gets hot first and it expands, grows lighter, and rises up the middle of the flask. The colder and heavier water at the top comes down to take its place. So each particle of water gets its turn of being in the middle over the flame, and each particle moves away with the heat the flame has given it and thus lets other particles come in to get heated. The particles go on moving up and down, each time getting hotter and hotter until boiling-point is reached. Then they cannot get any hotter. A current that is caused by heated particles *moving away* with their heat is called a *convection current*. All liquids and gases form convection currents when they are heated from below.

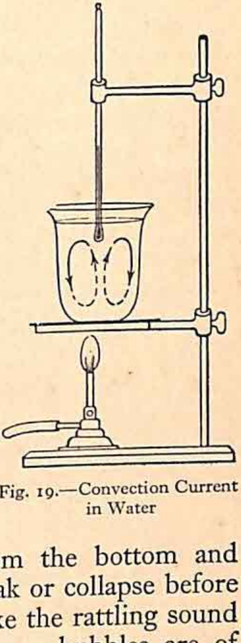


Fig. 19.—Convection Current in Water

Thirdly. Large bubbles rise from the bottom and seem to try to reach the top, but break or collapse before they get there. In breaking they make the rattling sound which we call "singing". These large bubbles are of steam. (Steam is water in the form of gas—it might be called "hot gas water". The hot water you wash in is really "hot liquid water", and ice is "solid water". The great thing to remember is that steam and ice are really water.)

The reason why these first steam bubbles break is because the water near the top of the flask is cooler than they are, and so they are turned back to water. Steam when cooled turns to (liquid) water.

Soon numbers of large steam bubbles rise from *all parts of the water*. They burst at the top with a " singing " noise and come off as steam. The reason why steam makes such very big bubbles is because it takes up much more space than water. A drop of water turning to steam would make a bubble the size of a tennis ball! If steam took up no more room than water it would not come out of the kettle at all, there would be room for it inside.

Fourthly. All this time the mercury in the thermometer has been going up and up. It started perhaps at 28° C. and now has reached 100° C. It will not go up any farther so long as it is in the water or steam. The water is at 100° C. and the steam is at 100° C. No matter how much you heat them they can't get any hotter and the mercury won't move. All the heat you can give goes to turning the water into steam. Steam really holds a great deal more heat than water even though the thermometer does not show this. If you get scalded by steam you will be burnt much more seriously than if you were scalded by boiling water. All the extra heat you used to turn the water at 100° C. to steam at 100° C. will come out again and burn you. If any of the heat in steam is taken away it turns to water again.

Fifthly. On the sides of the flask there is a mist and some drops of water trickle down. The mist is really made of tiny specks of water which later join to form big drops. The mist has been formed by some steam touching the cooler glass and being turned back to water.

Sixthly. Out of the top of the flask a cloud rises. You can't see the steam near the mouth of the flask—it is invisible (see fig. 18), but farther away it is like smoke. This is because the air of the room has cooled it and turned it into tiny particles of water. The clouds in the sky are also made of tiny particles of water. The steam near the mouth has not yet been cooled, so it is still steam and not liquid water. Steam is invisible.

If you go on heating the flask long enough all the water will disappear as steam. Kettles are sometimes spoilt by being left on the fire when all the water has been boiled out of them. Once water is boiling it can't get any hotter and it can't remain water—it *must* turn into steam; but to do this it must have heat given to it. It gives all this heat back again when it cools.

Sometimes the lid of a kettle will jump up and down. This is because the spout is so narrow that the steam can't escape quickly enough, so it forces its way out by lifting the lid. If you could stop up the spout of a kettle and tie down the lid, the steam would probably break the kettle.

This pushing power of steam has been used to make trains and ships move. The steam is shut in and has to push its way out, and the thing it pushes against makes the machinery work.

EXPERIMENT 26. *What to do.* Take a strong test-tube with a little water in it.

Put it into a test-tube holder and cork it firmly. Hold it at arm's length and with the cork pointing away from you. Heat the water until it boils.

What happens? The cork pops out.

Why did this happen?

Why is it dangerous to cork the tube too tightly or to take a cracked tube?

EXPERIMENT 27. *What to do.* Boil a kettle or flask with a little water in it. Hold a saucer, plate, or piece of slate in the steam.

What happens?

Why does this happen?

EXPERIMENT 28. *What to do.* Take a flask half full of water. Heat it until the water boils. Put out the burner. Fit a balloon over the top of the flask. Wrap a cold damp cloth round the bottom of the flask where the hot water is.

What happens? The balloon is drawn or pushed into the flask. It turns inside out.

Why this happens. The steam in the flask has been cooled and has turned back to water. The water takes up much less room that the steam did, and so there was an empty space in the flask. The air from outside went in to fill this space, and in doing so, it pushed the balloon down into the flask. How could you make the balloon come out again without touching it?

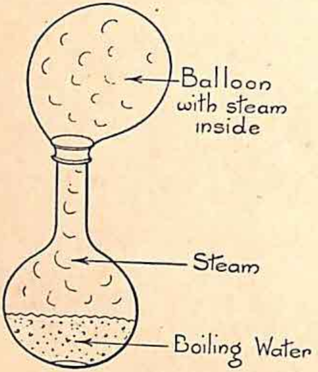


Fig. 20 *a*

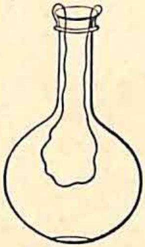


Fig. 20 *b*.—Steam condenses; Balloon pushed in

Experiment 29. When the mercury in a thermometer goes *up* it shows that heat is being *taken in*. When the thermometer goes *down* it shows that heat is being *given out*. Heat some water to boiling-point. Take away the burner. Put a second thermometer into the water.

What happens?

Why?

Where does the heat go when both thermometers are falling?

Learn this:

Boiling is the turning of a liquid into a gas at a definite temperature called boiling-point.

The boiling-point of water is 100° C.

A convection current is set up by the heated particles of a liquid or a gas expanding, becoming lighter and rising, and by the cooler particles coming down to take their place.

Steam takes up much more space than the same weight of water.

QUESTIONS

1. When steam turns to water scientists say: " The steam has *condensed* to water ". Read this chapter through again, and write down three sentences in which the word *condense* might have been used.

2. Why does it usually take longer to boil water in an open saucepan than in a kettle?

3. Why are there often drops of water inside the lid of a kettle?

4. Why does the lid of a kettle rattle?

5. " Steam is invisible "—then why do you see it coming out of the kettle spout?

6. Fill in the missing words:

(*a*) When water is heated the —— in it is driven out.

(*b*) Steam bubbles are large because —— .

(*c*) When water is heated a current is set up. The heated particles go —— the —— . The cooler particles go —— the —— .

(*d*) The heated particles —— because the heat has made them —— .

(*e*) The cooler particles —— because they are —— .

7. Why is a scald from steam worse than one from boiling water? What happens to the steam when it touches you?

8. What are the three chief differences between boiling and evaporation?

9. What are the two chief differences between convection and conduction?

10. Why would it be impossible to heat a solid by convection?

CHAPTER VI

Magic Heat

You have learnt that heat can travel in two ways: (1) by conduction—that is, by the heated particles passing their heat on to other particles touching them; (2) by convection—that is, by the heated particles actually moving away with their heat, thus leaving room for cooler particles to come down and be heated.

There is a third way, which is perhaps the most wonderful of all. It is called radiation.

The sun is ninety-three million miles away from the earth. The sun is very hot, so hot that scientists think there are no solids in the sun. All the substances are liquids or gases. The sun heats the earth; we can feel its heat. Yet the heat cannot possibly get to us by conduction, because there are no molecules or particles of matter between us and the sun. The air goes up about two hundred miles. So there is a space of millions of miles with no air in it. The heat, for the same reason, could not possibly reach us by convection either. Yet scientists tell us that it takes only eight and a half minutes for the heat of the sun to reach us. They believe that all this space is filled with ether; they call it *the* ether to distinguish it from the liquid ether that doctors and dentists use. They say the ether is " all-pervading ", that means, that it is everywhere. It is in between the particles of molecules of the air, and of water, and of all substances, and it is even in vacuums. What the ether really is no one knows!

The molecules of matter in the sun are moving very, very fast, and it is believed that they make ripples or waves in the ether. You can make ripples in a pond by throwing in a stone. The water ripples travel out in all directions, and if they meet a floating stick they move it along. The waves in the ether travel to the earth, and when they strike it they make the molecules of the earth vibrate and then we say, " it is warm ". The heat of the sun does not warm the ether or the air. The vibrations simply hit the earth and make it warm.

Heat then travels through the space between the sun and the earth without heating it. Heat is produced in the earth itself, and the hot earth heats the air above it as an oven heats water. The air near the warm earth gets heated and rises and cold air takes its place. A convection current is set up.

If you stand in front of a fire, your face will get very hot, but anyone behind you will be screened by you. The fire heats you by radiation. It does not heat the air of the room very much, because the convection currents go up the chimney, and air is a bad conductor.

Now let us see how a big house that has central heating gets warmed.

At the bottom of the house is a boiler made of iron. It looks like an enormous box. The boiler gets heated by the fire underneath it. The iron it is made of passes the heat from particle to particle till all the box is hot. Thus the boiler itself is heated by conduction.

The water in the boiler gets heated by convection; the hot water rises and passes out by the pipe at the top. It goes through the pipes and radiators in the different rooms. As it goes along it gets cool, and comes down again by another pipe which leads into the bottom of the boiler. In the pipes there is a constant flow of water, the hottest passing up and the coolest passing down.

The pipes themselves get heated by the hot water touching them, that is by conduction. They give out heat to the room (1) by heating the air above them and

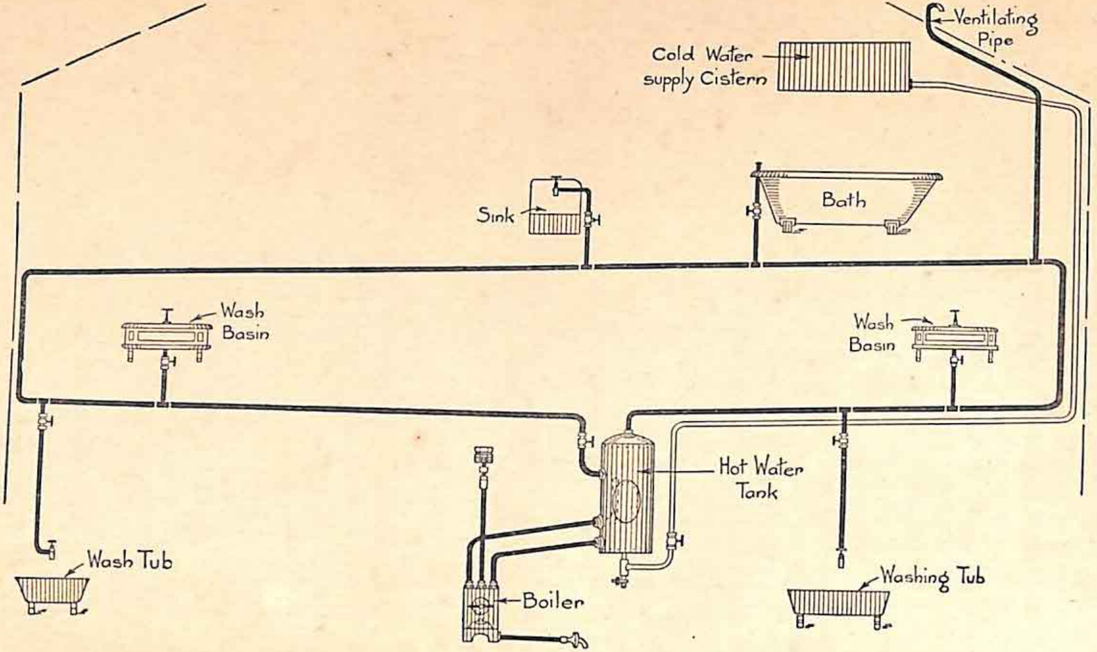


Fig. 21.—How a House is Heated

thus setting up convection currents; (2) by radiating heat in all directions through the air to the objects in the room.

Heat radiated from the sun or from fires or pipes does not heat all objects equally. Things that have a dull black surface get heated most quickly, but they also lose heat quickly. Black kettles take in heat quickly, but lose it quickly. Shiny copper kettles take in heat slowly, but keep it a long time. The earth takes in heat quickly and loses it quickly. Water takes in heat slowly but keeps it a long time. So we say: " Black kettles are good absorbers and good radiators." (To absorb means to take in.) " The earth is a good absorber and a good radiator." " The sea is a slow absorber and a slow radiator." The earth gives out during the night much of the heat which it has received from the sun during the day. That is why it is so cold in the early morning; the earth has been giving out heat all night. As summer goes on, the earth gets warmer and warmer. The sea, too, takes in heat, but much more slowly, so that in summer we go to the seaside because it is cooler there. In autumn the land is losing heat, and so is the sea, but more slowly than the land. About January, the land is at its coldest, and the sea is also at its coldest. But though the sea received less heat than the land it has, as it were, been more economical! So in winter the sea is warmer than the land. These facts will help you a great deal in your geography, when you study winds.

Experiment 30. Pour a quart of water into a black kettle and another quart into a shiny tin or copper kettle. Time them and see which is the first to boil. Be sure that they are both equally heated. Let them cool. Put a thermometer into each, and see which reaches 40° C. first.

Experiment 31. Take a magnifying glass and hold it in the rays of the sun over a piece of paper. Move it about until the paper is scorched. Is the glass much heated? How did the heat reach the paper, by conduction, convection, or radiation?

LEARN THIS:

Heat passes by radiation from the sun to us without heating the air.

Fires and hot pipes radiate heat in all directions.

Dark objects with rough surfaces are better absorbers and radiators than bright smooth objects.

QUESTIONS

1. Why are kettles often black and rough, and teapots always smooth and shiny?

2. Why are hot-water pipes generally rough and black?

3. If you want to keep a bottle of water warm, would you put it on top of the hot pipes or underneath them? Why?

4. What do you mean when you say " the land absorbs heat "?

5. What do you mean when you say " the sun heats the air indirectly "?

6. When you toast a piece of bread in front of the fire is it heated by conduction, convection, or radiation?

7. Why does a stove give out more heat to a room than an open fire?

8. Why is the pipe that leads the hot water out of the boiler at the top, and the pipe for the entrance of the cold water at the bottom of the boiler?

9. What would happen if all radiation of heat was suddenly stopped?

10. What would happen if the space between the earth and the sun were filled with air?

CHAPTER VII

How Water breaks the Rules

There are two rules which you learnt in Chapter III.

1. *Rule of contraction.* When cooled,
   - (*a*) a gas contracts until it becomes a liquid;
   - (*b*) a liquid contracts until it becomes a solid;
   - (*c*) a solid contracts.
2. *Rule of expansion.* When heated,
   - (*a*) a solid expands until it becomes a liquid;
   - (*b*) a liquid expands until it becomes a gas;
   - (*c*) a gas expands.

Now water does not keep these rules perfectly. After reading this chapter you will be able to say exactly which rules it breaks. If you take one of those cubes of wood used in the Infant School and put it in water it will float. This is because one cubic inch of wood weighs less than one cubic inch of water.

If you put one cubic inch of lead into water it will sink because it weighs more than one cubic inch of water.

If you put a teaspoonful of oil on water it will float because it is lighter than a teaspoonful of water. A teaspoonful of mercury will sink because it is heavier than a teaspoonful of water.

When you are comparing the weights of two substances you must always take the same bulk or volume of each. If you take a cubic inch of one you must take a cubic inch of the other. It would be absurd to take a sack of flour and a handful of sand and say, " flour is much heavier than sand."

You must have the same volume or bulk of each. Volume is the amount of space a thing takes up. To compare the weight of sand and flour you must take a sack of each, or a glassful of each.

You know that ice floats on water. That means that ice must be lighter than water. When the water freezes it expands, and so gets lighter and rises. If water contracted when it froze, it would take up less room and be heavier, bulk for bulk, than the water. If it is really true that water expands when it freezes, then it must contract when it melts or thaws. To prove these two facts you must do some experiments.

EXPERIMENT 32. To show that water expands when it freezes (fig. 22).

What to take. Bottle, a two-holed cork, a long bent tube, a beaker or jam jar, some ice or snow and salt, a piece of paper for a scale, a thermometer.

What to do. Fill the bottle with water. Put the thermometer and glass tube through the holes in the cork. Fit the cork into the bottle, and mark the level of the water. Hold the bottle in the jam jar so that the top is just seen. Pack ice, mixed with salt, all round and underneath the bottle. Watch the water and the thermometer.

What happens?

Why?

EXPERIMENT 33. To show that water exerts great pressure when it turns to ice.

What to take. A bottle with a screw-on cap and a cork to fit inside it. A long pin, water, ice, and salt.

What to do. Fill the bottle with water. Put in the cork with the pin down the side of it. Some water will be forced up where the pin is. Take the pin out and screw on the cap. It is very important there should be no air between the water and the cork. Hold the bottle in a pail and pack ice and salt round it. Leave it for a few hours.

What happens?

Why?

Experiment 34. To show that ice contracts on melting (fig. 23).

What to take. A bottle, a two-holed cork, a piece of bent tubing, a thermometer, water, and ice.

What to do. Put as much ice as you can into the bottle. Then fill it up with very cold water. Put the thermometer and tube through the holes in the cork and see that the tube goes far down into the bottle, and that the 0° mark on the thermometer is well above the cork. Watch the thermometer and the level of the water in the tube.

What happens?

Why?

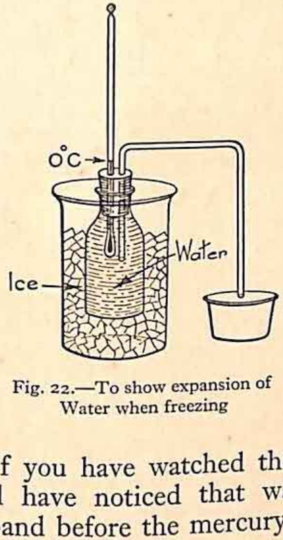


Fig. 22.—To show expansion of Water when freezing

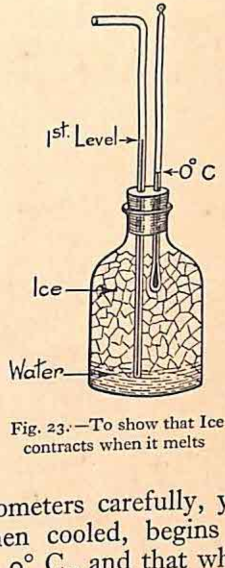


Fig. 23.—To show that Ice contracts when it melts

If you have watched the thermometers carefully, you will have noticed that water, when cooled, begins to expand before the mercury reaches 0° C., and that when the ice is heated, the water goes on contracting after the mercury has passed 0° C. The exact point where the change takes place is 4° C. Fig. 24 will help you to understand exactly what happens.

Reading from the top down the cold side.

Steam takes up hundreds of times more space than water.

When cooled:

Steam contracts till it turns to water.
Water contracts till it reaches 4° C.
Water at 4° C. expands till it reaches 0° C.
At 0° C. it expands still more and freezes.
Ice contracts but always remains lighter than water.

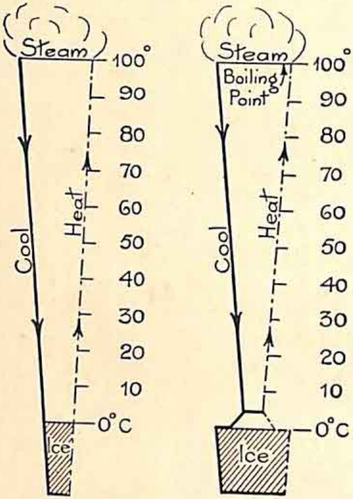


Fig. 24

If Water kept the rules

How Water breaks the rules

Reading from the bottom up the hot side:
Ice takes up more space than the same weight of water.

When heated:

Ice at 0° C. contracts and becomes water at 0° C.
Water at 0° C. contracts until it reaches 4° C.
Water at 4° C. expands until it reaches 100° C.
Water at 100° C. turns to steam and expands.

Let us think for a minute what would happen if water kept all the rules. It would contract when it turned to ice and sink to the bottom of the pond. The fish down there would come above it so as to keep in water. The water at the surface of the pond would be exposed to the cold and so it would keep on sinking and freezing. In the end the fish would all be on top of the ice, and there would be no places for them to hide, and no food for them to eat. As it is, the coldest water rises and freezes at the top, covering the pond with ice which forms a protection for the water below, preventing it from cooling so quickly. Fish generally live far down where the water is heaviest, and about 4° C. Then again, if ice sank it would be difficult to see it, and this would make navigation dangerous. Moreover, the ice would take much longer to melt, and so many rivers and lakes would be blocked with ice all the year round.

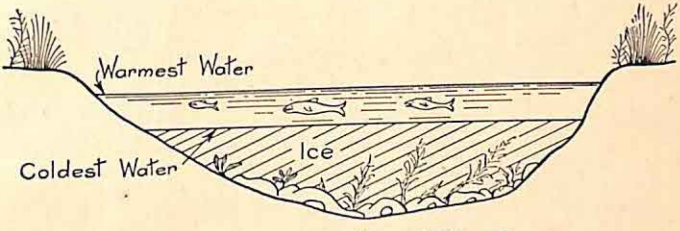


Fig. 25*a*.—What would happen if Ice sank

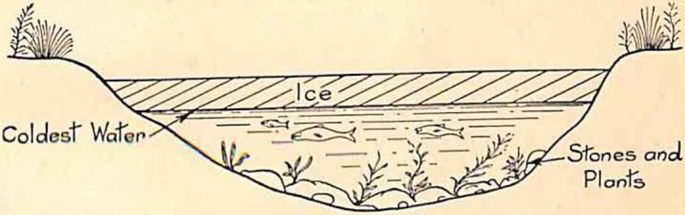


Fig. 25*b*.—Why Ice floats

Here are some examples of the results of the expansion of water on freezing: In frosty weather the gravel on a path stands much higher than usual. The pebbles are farther apart, and there are holes.

Water-pipes are cracked in cold weather because the water in them turns to ice. The water does not flood the house until the thaw sets in, and the ice in the pipes melts. So some people who do not think say that it is the warm weather that bursts the pipes!

When rain falls it often fills little cracks or holes in the rocks. When the water freezes it expands and forces the rock apart. When the thaw begins the ice melts, and the rock is left with a wider crack than it had before. If this happens again and again, the rock will be split up! This is what people mean when they say: " Frost wears down mountains." In Norway, where there are many rocky mountains, the people used to think that their god Thor had been knocking pieces off the mountains with his great hammer!

Plaster of Paris is another substance which breaks the rule. When a cast, such as you see in art rooms, is made, the liquid plaster is poured into a mould. When it solidifies, it expands, and so presses into and fills the tiniest crevices in the mould. If plaster of Paris contracted on solidifying, we should never get such perfect detail in our casts.

LEARN THIS:

Water is heaviest and takes up least room when its temperature is 4° C.

Water expands when it freezes.

Volume is the amount of room a body takes up.

When comparing the weight of two substances you must take the same volume of each.

QUESTIONS

1. Which of the rules on page 43 does water keep and which does it break?

2. At the foot of mountains you often see heaps of sharp stones. Where have these probably come from? How did they get there?

3. A bottle filled with ice-cold water is warmed by being kept in a warm room. Explain the changes in volume that would be noticed.

4. Why is it incorrect to say that water-pipes burst when it thaws after a period of frost?

5. Why does cream rise to the top of milk? How could you prove that your answer was correct?

6. What would you do in order to find out which was heavier, (*a*) plasticine or clay, (*b*) water or methylated spirits? (Do not mix them together.)

CHAPTER VIII

The Unseen Force that pulls us All

You have learnt in your geography that the earth is a globe, and perhaps you have wondered why we don't fall off it. When you look at a globe and imagine people on the opposite side, it does really seem as if they must be upside down with their heads hanging down in space and their feet up on the earth!

We are all kept on the earth by a force called gravity. Gravity pulls us towards the centre of the earth. It is just as if we were tied to the centre of the earth by a piece of stretched elastic. We jump up and down we come again. You throw your ball into the air, it goes up and up, stops a second, and then down it falls. It is pulled down by the unseen force of gravity.

No matter on which side of the globe you are, " down " always means towards the centre of the earth and " up " always means away from the centre of the earth. So no one with his feet on the earth can be upside down!

You have often seen water running downhill. It does this to get nearer to the centre of the earth. It is being pulled down. If you tilt your jug, the water pours downwards into your basin. In the basin the surface of the water is flat and horizontal. Unless you stir it there are never any little hills of water. Gravity is pulling on every particle of water, and each particle gets as near the centre of the earth as it can. If there were a hill in the basin the particles of water at the top would immediately run down to get nearer the earth. That is why the surface of an undisturbed liquid is always flat.

This pull of the earth on us we call our *weight*.

Heavy things like lead shot and stones are pulled more strongly than light things like feathers and cork.

To find the weight of an object or the strength of the earth's pull on it, we use a spring balance. You should try to make one yourself out of a clock spring with a piece of cardboard on which to mark the graduations. In Great Britain we compare the strengths of the earth's pull on different objects by its pull on a certain mass or lump of platinum kept by the Board of Trade. We call the amount of matter in this lump of platinum "one pound", and the pull of the earth on it we also call "one pound". So the first thing you must do with your balance is to hang a one-pound mass on it, and mark how much the spring stretches. Then mark the pull exerted by the earth on half a pound and on a quarter of a pound. After that you can use your balance to find the weight of different objects.

If you take your ruler and try to balance it horizontally on your finger, you will find that you succeed when your finger is at the middle point of the ruler. It is as if the imaginary elastic was tied to the middle point. This point, where the pull of the earth, or the weight of the ruler, acts is called the *centre of gravity* of the ruler.

Now try to balance the ruler vertically on one finger. You immediately move your arm and perhaps begin to walk about. The pull of the earth acts vertically down, that is, the imaginary elastic pulls from the centre of the ruler vertically to the ground. If the elastic falls outside your finger and the end of the ruler, down falls the ruler. To keep your finger under the point where the weight or elastic acts, you move your arm so as to get your finger vertically under the centre of the ruler.

Your body has a centre of gravity too. It is inside you in the very middle of you. If you partly sit on one chair and put your head and shoulders on another chair some distance away, it will not be difficult for a friend to find a point on your back where you can be held up and balanced perfectly, just as the ruler was! That point must be just below your centre of gravity.

When you trip up over a stone, you fall forward. This is because your body and legs were moving forward. Your legs are stopped but your body goes on, and so you lean forward and your centre of gravity comes to be beyond your feet and so you fall down.

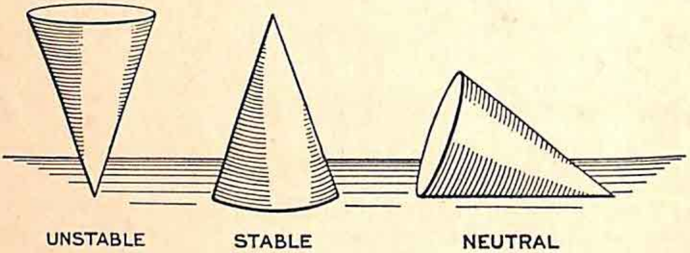


Fig. 26*a*

When a thing is very steady and is not easily knocked over, we say that it is *stable*. A plate is stable because it has a wide base or bottom to stand on. A tall vase of flowers is often unstable because the centre of gravity of the vase and flowers is too near the top. The slightest push brings the invisible elastic or pull of gravity beyond the base of the vase and over it goes. There are little toy men to be had that are impossible to knock

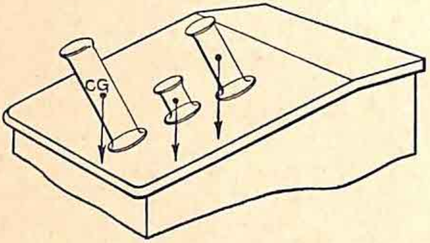


Fig. 26*b*

These Jars are on a Desk: Which will fall over? Which is steadiest?

down. They always bob up again! This is because they are weighted so that their centres of gravity are near the bottom.

To make a thing stable you must:

(1) Get the centre of gravity as near the base or bottom as possible. (You can sometimes do this by adding weights.)

(2) Make the base as broad as possible.

Everything in the universe attracts or pulls everything else. We say therefore that everything exerts a force of gravity or gravitation. When we speak of gravity we often think only of the earth's pull. That is because the earth is so very big compared to the things on it, that its pull is always the strongest. The earth's pull wins.

The sun is pulling the earth, and the earth is pulling the sun. The sun is much bigger than the earth and it would win if the earth were not moving round the sun so fast.

The earth is pulling the moon, and the moon is pulling the earth. The earth is larger than the moon and it would win if the moon were not moving so fast.

The sun pulls you and the earth pulls you. The earth wins because the sun is 93 million miles away from you.

The earth pulls a stone thrown into the air and the stone pulls the earth. The earth wins because it is so much bigger than the stone.

The big tree outside is pulling you and you are pulling the big tree, but neither wins because the pulls are much too feeble even to be noticed.

Experiment 35. Why I fall over.

What to do. Stand with the whole length of your right foot touching the wall. Raise your left foot.

What happens?

Why?

EXPERIMENT 36. When do things fall off the table?

What to do. Take a rule, a pen box, a cube, and a wooden cylinder. Put them one by one near the edge of the table, and then move them very slowly over the edge of the table.

When do they fall?

EXPERIMENT 37. *What to do.* Take a cork that has a rounded wooden top to it. (If you cannot get a cork like this, then try a glass stopper or a ball.) Fit it into a cardboard cylinder about 5 inches long (such as is used for postage). If necessary use some gum or seccotine to fix in the cork. Now experiment with paper or wood shavings, and lead shot or pebbles. Put these in and find arrangement that makes the cylinder:

(*a*) difficult to knock over;
(*b*) very easy to knock over;
(*c*) roll about on its side and refuse to stand up.

LEARN THIS:

Gravity is the force by which things are attracted to each other.

The strength of this force depends on the mass of the bodies and their distance apart.

The earth is so large that it exerts a very strong force of gravity which keeps us all from falling off.

The centre of gravity of a body is the point where this pull or weight acts.

An object is stable when it has a broad base and when its centre of gravity is low down.

The weight of an object is the pull of the earth on it.

QUESTIONS

1. Why do we speak of falling "down" and of jumping "up"?

2. Where is the centre of gravity of a ball?

3. Why is it easier to knock you over if you are sitting on the top of a light ladder than if you were sitting on a chair?

4. Why is it dangerous to stand up in a canoe?

5. Why do you stand with your feet apart when you are fighting?

6. Why do sailors put ballast or extra weight in their ships?

7. Why do sailors swing from side to side when they walk?

8. Draw three vases for flowers. Mark the one you think (*a*) the most stable, (*b*) the most unstable.

9. Name 8 things in the house that are very stable, and 8 things that are unstable.

10. Put yourself into 5 positions: in the first one you must be very stable, in the second one less stable, and so on, until in the fifth you are easily tipped over.

11. What do we mean when we say something is "top heavy"?

CHAPTER IX

The Unseen Force that presses on us All

The earth is surrounded by a case of air more than 100 miles high. Each of us is supporting a vast column of air, which presses with a weight equal to 15 lb. on every square inch of us. This weight would crush us if we had no air inside us that presses up.

The higher you go up in the air, the shorter is the column of air above you, so that the weight pressing on you is less. If you go down a mine, the column of air above you will be higher and the weight on you will be greater. Mountain climbers and men in aeroplanes sometimes suffer from their eyes and ears bleeding. This is because the pressure in their bodies is greater than the pressure of the air.

A balloon filled with air will explode when it is very high up, because the air inside it presses out and up and in all directions, and the air outside does not press to keep it in. If the air ceased to press on the water in the oceans, they would all evaporate.

To understand how the pressure of the air makes water flow uphill, you must do an experiment (see fig. 27).

EXPERIMENT 38. What makes water flow upwards?

What to do. Take a broad and a narrow piece of glass tubing about 2 feet long. Join them by a piece of rubber tubing about the same length. Clamp the tubes vertically into retort stands. Colour some water with eosine or red ink or litmus and pour it through a funnel into the broad tube. Stop pouring when you see about 6 inches of water in the narrow tube, above the rubber tube. Raise and lower the narrow tube.

What happens? (Take a long ruler and hold it horizontally to show the levels of the water.)

The reason that the water is at the same level in both tubes is because the air presses equally on both surfaces. Some people express this by saying: "Water seeks its own level." This fact is made use of in supplying houses with water.

EXPERIMENT 39. How our houses are supplied with water.

What to do. Take a large aspirator and fit it with a one-holed cork with short glass tube passing through it. Join on a long piece of rubber tubing, and to the end of that a long piece of narrow glass tubing. Put a stop clip on the rubber tubing (fig. 28).

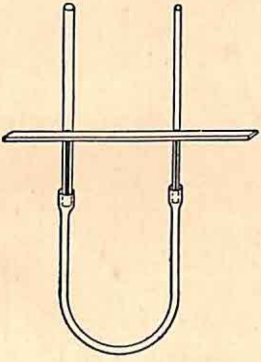


Fig. 27.—Water rises to the same level in both Tubes

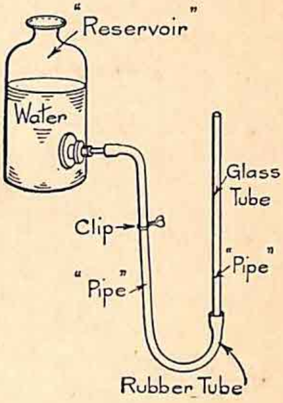


Fig. 28

Pour water into the aspirator.

Hold the glass tube vertically and high above the aspirator.

Open the clip. Move the glass tube down slowly.

What happens?

Why?

The aspirator represents the reservoir of water that is high up outside the town. The rubber tube represents the underground pipes, that conduct the water to the town, and the glass tube represents the pipes that go up the sides of your house.

If your house is higher up than the reservoir, the water will not reach it. You will have to use a pump.

If your house is lower than the reservoir, the water will run up the pipes and fill the tank at the top of the house.

EXPERIMENT 40. How to make a fountain.

What to do. Take the same apparatus as for Experiment 39, but put a fine glass jet on instead of the long glass tube. Hold the jet high above the reservoir. Open the clip and lower the jet slowly.

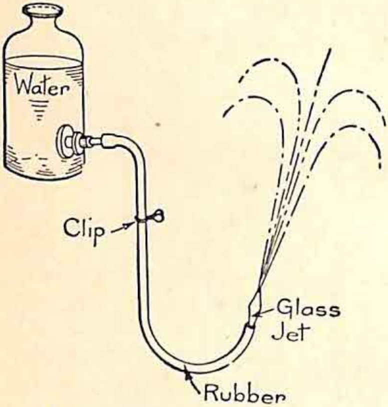


Fig. 29.—How to make a Fountain

What happens?

What forces the water up?

Why does it never reach the level of the reservoir?

We measured the pull of the earth by using a spring balance. To measure the pressure of the air we use an instrument called a barometer.

Experiment 41. How to make a barometer.

What to do. Take a tube closed at one end and about 36 inches long. Use a funnel and fill it with mercury. Pour mercury into a little china bowl. Put your finger over the open end of the tube, and turn it over so that the closed end points up, and the open end down. Put the open end, with your finger over it, under the surface of the mercury in the bowl. Remove your finger. Clamp the tube in an upright position.

What happens?

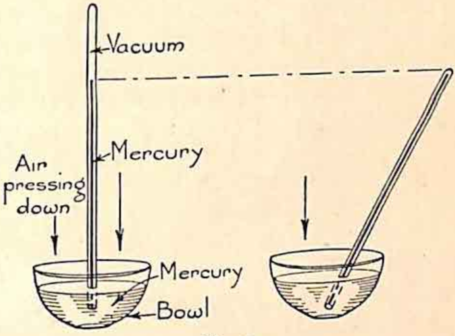


Fig. 30

What is in the space above the mercury in the tube?

Measure the height of the column from the surface of the mercury in the bowl.

There is a column of mercury about 30 inches high standing up in the tube. What is holding or pulling it up? There is nothing in the space above the mercury, there could not be anything there, because you filled the tube with mercury and kept your finger over the end. No air could have got in. This space is a vacuum, so there is nothing in it to pull the mercury up or to push it down. Slant the tube, and you will see that this is true, because the mercury will run right up to the top. If there were air there, the mercury could not do this, for there can never be two things in the same place at the same time.

If you are on a see-saw and the other person is heavier than you are, *up you go*. If you are heavier, then *down you* *go*. Now the barometer acts something like a see-saw. The column of mercury is at one end, and an invisible weight is at the other. This "other end" is all the *surface* of the mercury in the bowl. When the invisible weight presses hard on the surface of the mercury in the bowl, up goes the mercury in the tube. When the invisible weight presses lightly on the surface of the mercury in the bowl, down comes the mercury in the tube.

In other words, the pressure of the air usually balances 30 inches of mercury.

When the pressure increases the mercury goes up or rises.

When the pressure lessens the mercury goes down or falls.

When the barometer rises we say: "The weather is going to be fine," and when it falls, we say: "It is going to rain." We know this because:

Dry air is heavier than moist air.

When the air is dry the invisible weight is greater, and so the mercury in the tube is pushed up.

When the air is moist the invisible weight is less, and so the mercury in the tube falls.

Now suppose you walked up a hill with your barometer. As you go up the mercury in the tube will fall. It will fall about one inch (we must say *about* one inch, because the air near the earth is heavier than the air higher up; it is more pressed together and thicker or denser) for every thousand feet you go up. If you were able to climb Ben Nevis the barometer would have fallen 4 inches. How much would it fall if you climbed Mount Everest or Mont Blanc?

Suppose you took your barometer down a mine. The farther you went down, the more air there would be above you, so the barometer would rise.

Barometers are sometimes used to tell people how high they have climbed. When the barometer has fallen half an inch they know that they must have climbed about 500 feet. When it has fallen 1 inch they have climbed about 1000 feet.

LEARN THIS:

The air presses down on us.

Water tends to rise until it is all at the same level.

A barometer is an instrument for measuring the pressure of the air. It is used for foretelling the weather, and for measuring the heights of mountains.

The pressure of the air usually balances 30 inches of mercury. Its pressure equals a weight of about 15 lb. on every square inch.

The barometer rises when the weather is likely to be fine, because dry air is heavier than moist air.

The barometer falls when the weather is going to be wet, because moist air is lighter than dry air.

QUESTIONS

1. Draw two teapots, one of which would be sure to spill tea out of the spout when it was filled, and one that would not spill any tea.

2. Why do springs of water bubble up?

3. Why are taps turned down? Give two reasons.

4. Why does a fountain not reach the level of its reservoir?

5. Draw a picture of a hill cut through so as to show the inside of a reservoir, and all the underground pipes leading to a house at the foot of the hill with a fountain playing in the garden.

6. What would happen if you let air get into the top of your barometer tube?

7. What is the advantage of using mercury in a barometer instead of water? (Mercury is $13\frac{1}{2}$ times heavier than water.)

8. What would happen if the air stopped pressing on us? Give six examples.

CHAPTER X

A Mixture on which our Lives Depend

If you have got a pet rabbit, perhaps you sometimes feed him on a mixture of bran and tea leaves. When you look at the mixture you can see the brown tea leaves and the grains of bran, and if you had time and patience you might be able to separate them again.

EXPERIMENT 42. Mix some iron filings with sand. Then take a magnet and separate them.

EXPERIMENT 43. *What to take.* A funnel, a filter paper, 2 beakers, an evaporating basin, a tripod, a retort stand, wire gauze, bunsen burner, water, and a mixture of salt and sand.

What to do. Pour a little water, just enough to dissolve the salt, on the mixture in the beaker. Fold a filter paper (see fig. 31) and put it into the funnel. Support the funnel in the ring of the retort stand, and place a beaker underneath it.

Pour the salt water with the sand into the filter and let the water run into the beaker underneath.

Pour the salt water into the evaporating basin and heat it on the tripod with wire gauze between it and the bunsen burner.

What happens?

Why?

From these experiments you will see that a mixture is not very difficult to separate. The ingredients are not changed, even though they are mixed. Sugar will still be sweet, and have the other properties of sugar, even though it is mixed with sand or salt.

If you were to put four tablespoonfuls of water into a glass and one tablespoonful of wine into another glass, and then pour the wine into the water, you would have a *mixture* of wine and water. You could say: " This mixture is in the proportion of four volumes of water to one of wine." In other words, one-fifth of the mixture would be wine and four-fifths would be water, because altogether you took five tablespoonfuls. If you had taken four tablespoonfuls and then one teaspoonful you could not have said that the proportion was four to one. Now the wine spreads right through the water. No part is a deeper red than the rest. It is all equally reddened. If you dip your finger in or sip it, you will find it tastes of wine all through.

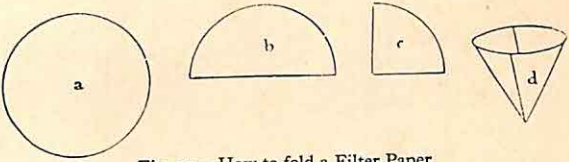


Fig. 31.—How to fold a Filter Paper

Instead of wine you might have put in a tablespoonful of vinegar. You would not be able to see the vinegar, but you could taste it, and know that it had spread all through the water, and was still vinegar.

Making these mixtures of four parts by volume of water, and one part of wine or vinegar, helps us to understand what the air is made of. The air is a mixture, not of two liquids, but of two gases. One of these gases, like the water, takes up four times as much room as the other. This gas is called nitrogen. The other gas is like the wine or vinegar, and it takes less room. It is called oxygen. Oxygen is the gas that keeps us alive. The nitrogen, as it were, dilutes or weakens it. Oxygen would be too strong for us if it were not mixed with so much nitrogen, just as vinegar would be too bitter and wine too strong without water.

Oxygen has no taste and no colour.

Nitrogen has no taste and no colour.

Oxygen is active; that means it is always joining with other substances and changing them.

Nitrogen is inactive; it does not readily join with other substances.

It is this difference in activity that makes it easy to get the oxygen out of the air. If the air were a compound and not a mixture we could not get the oxygen out to breathe. In fact, when nitrogen and oxygen are joined they don't behave like oxygen and nitrogen at all. They sometimes form " laughing gas ". Now " laughing gas " puts people to sleep and makes them laugh, so it would be a dreadful thing if the oxygen and nitrogen of the air joined to make it! We should all die.

When we breathe we use up oxygen. When a candle or match or anything else burns it joins with oxygen. Iron-rust is simply iron joined to oxygen to make a compound called oxide.

EXPERIMENT 44. The oxygen of the air joins with copper and lead when they are heated strongly. In this experiment you will take some lead oxide or red lead and by heating it get back or set free some of the oxygen again.

What to take. A little red lead, a hard glass tube, a splinter of wood, a bunsen burner, a test-tube holder.

What to do. Put the test-tube with red oxide in it into the holder and heat it in the flame of the bunsen burner. When the powder has been heated five minutes or so, hold a glowing splinter of wood inside the tube.

What happens?

Why?

EXPERIMENT 45. To show that oxygen unites with iron.

What to take. Iron filings, muslin bag, glass rod, basin, glass jam jar, water.

What to do. Put the filings in the bag and weigh them. Then damp the bag, and tie it on the rod.

Set up the apparatus as shown in fig. 32. When you invert the jam jar in the water you will notice that the water inside the jar sinks because there is air in that jar that can't get out. Leave the apparatus for some days.

What happens?
Why?

Slip a glass plate over the opening of the jar and take it out of the water. Insert a taper.

What happens?

Let the bag of iron filings dry, and then weigh them.

What do you notice?

It is because the oxygen is so active that it has joined with the iron to make iron-rust.

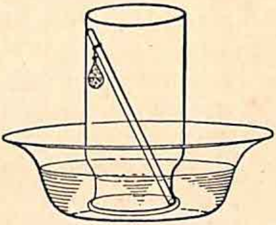


Fig. 32

When we breathe we take in air, that is oxygen and nitrogen. The nitrogen is no good to us so we give it out again. The oxygen, however, passes through our lungs into our blood and purifies it. It joins with carbon, and we give it out again in a gas called carbon dioxide. So we breathe in nitrogen and oxygen and we breathe out nitrogen and carbon dioxide.

A mixture of carbon dioxide and nitrogen is sometimes called " used up air ". It is not air at all. No one could live in it. You have heard the story of the Black Hole of Calcutta and how the people in it were suffocated and poisoned. They had used up all the oxygen and there was only nitrogen and carbon dioxide left.

Sometimes we say: " This room is stuffy." We really mean that most of the oxygen has been used up, and also that there is too much water vapour in the air. In such a room you will probably get a bad headache. Rooms must be ventilated. " Ventilation " comes from a Latin word that means "wind". To keep a room full of fresh air there must be a current or gentle wind passing through it. The bad air must go out and the good air must come in. There must be an opening for each, or else they will get in one another's way. If a person tries to come into a room and another person tries to get out at the same time, and the doorway is narrow, they will stop one another and neither will get in or out!

The air in a room gets warmed near the people in it by being breathed in, and so the " bad air " is warm and expands, getting lighter and rises. So we open a window or ventilator at the *top* of the room to let the bad air out. The cool fresh air outside rushes in. It is heavier so it comes in low down, perhaps under the door and through the keyhole! We open the bottom of windows to let fresh cool air in. In our rooms there is really a continual convection current (see Chapter V), warm air rising and cool air sinking and coming in.

An open fire is one of the best ways of airing a room in winter. The air in the fireplace gets hot, expands, gets lighter and goes up the chimney. Fresh air rushes in through every chink to take its place. But an open fire sends most of the heat up the chimney and so does not warm the room so well. Also it creates a " draught " across the floor.

A stove does not ventilate a room so well as an open fire, but it warms the air more and uses much less coal.

EXPERIMENT 46. To find out where the air comes in and goes out of a room.

What to take. A lighted candle.

What to do. Open the door *a little*, and hold the lighted candle: (1) near the floor, (2) near the handle, (3) near the top.

What happens?

In which direction is the flame blown? Close the door and hold the candle to the keyhole and to any other opening there may be.

Experiment 47. To show that a current is made by a burning candle (fig. 33A).

What to take. A long narrow lamp glass, soup plate, a candle, a piece of cardboard, paper, and water.

What to do. Stand the candle in the middle of the plate and pour water round it. Light the candle. Put the lamp glass over it. Leave it and watch.

What happens?

Why?

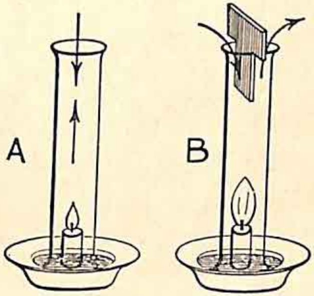


Fig. 33

Experiment 48. The same as Experiment 47 (fig. 33B).

What to do. Cut your cardboard into the shape of a T, and put it into the lamp glass so that the opening is divided into two parts. Light the candle with a taper. After it has been burning some time, light a piece of paper, and then blow it out and hold it, while it is still smouldering, near the top of the lamp glass.

What happens?

Why?

Hold your hands one on each side of the cardboard at the top of lamp glass. Do you notice anything?

Experiment 49. To show that a fire makes a current.

What to do. Hold a piece of thick brown paper in front of the fire:

(1) So that the lower part of the grate is open.

(2) So that the paper goes right down to the floor.

What happens in each case?

Why?

LEARN THIS:

In a mixture the ingredients are not joined, they merely lie side by side and each keeps its own properties. A mixture is easily separated.

In a compound the elements are joined and a quite new substance is formed. A compound is difficult to "undo".

Air is a mixture of two gases, oxygen and nitrogen.

It contains four-fifths or four times as much nitrogen by volume as oxygen.

The oxygen is active and the nitrogen is inactive.

Carbon dioxide is a heavy gas that is found in the air, because it is breathed out by animals and plants.

Ventilation means "airing", or making a convection current in the air.

QUESTIONS

1. Why do you get a headache in a badly ventilated room?

2. What is iron-rust?

3. Of what use is the nitrogen in the air?

4. Why is there a draught under your door?

5. Where are ventilators usually put in a classroom?

6. Why is it better to open a window a little top and bottom than to open it more at the top only?

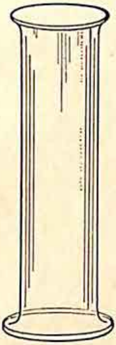
7. Why does smoke go up the chimney?

8. How would you separate a mixture of sawdust, sand, and sugar?

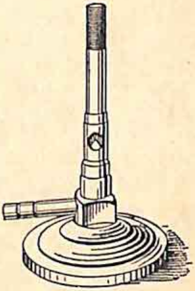
9. Draw a rectangle 3 inches long and 2 inches high, to represent a room. Put a flame to represent a fire in one corner, and draw arrows to show the direction of air currents.

10. What would happen if hot air were heavier than cold air?

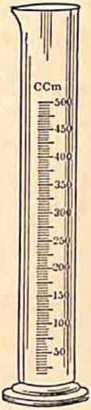
APPARATUS



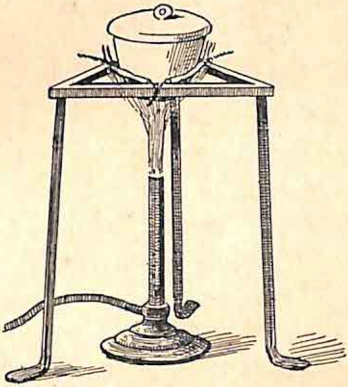
Gas Jar



Bunsen Burner



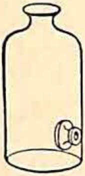
Measuring
Glass



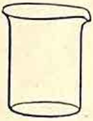
Bunsen Burner and Tripod, supporting Pipe Clay Triangle and Crucible (with lid)

On this and the following page are given illustrations of simple apparatus necessary for the experiments described

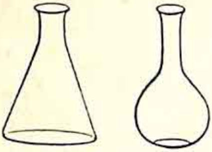
APPARATUS



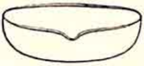
Aspirator



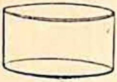
Beaker



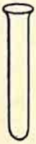
Flasks



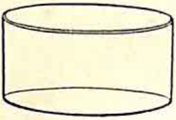
Evaporating Basin



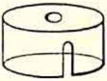
Crystallizing Basin



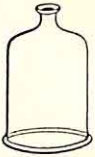
Test Tube



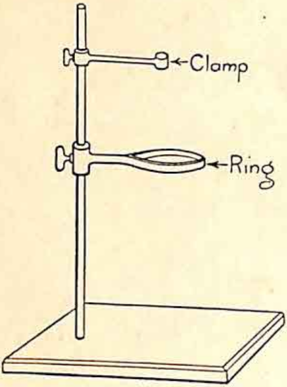
Trough



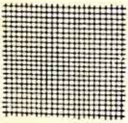
Beehive Jar



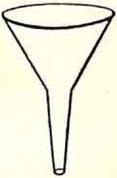
Bell Jar



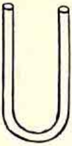
Retort Stand



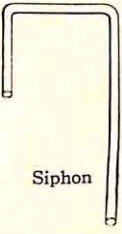
Wire Gauze



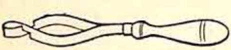
Funnel



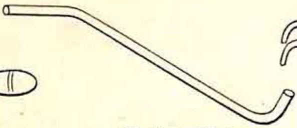
U Tube



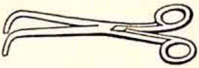
Siphon



Test-tube Holder



Delivery Tube



Crucible Tongs